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## INTERNATIONAL PRELIMINARY EXAMINATION REPORT


(PCT Article 36 and Rule 70)

|   |   |  |
|---|---|--|
| Applicant's or agent's file reference<br>BO 42545 dVr                                     | <b>- FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |  |
| International application No.<br>PCT/NL00/00418   | International filing date (day/month/year)<br>15/06/2000  | Priority date (day/month/year)<br>15/06/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>C22C33/02 |   |  |
| Applicant<br>SKF ENGINEERING & RESEARCH CENTRE B.V.                                       |   |  |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.  
  
☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).  
  
 These annexes consist of a total of 7 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

|   |  |
|---|--|
| Date of submission of the demand<br>15/01/2001  | Date of completion of this report<br>12.10.2001                          |
| Name and mailing address of the international preliminary examining authority:<br><br> European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br><br>Noske, W<br><br>Telephone No. +49 89 2399 8448 |



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/NL00/00418

**I. Basis of the report**

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

**Description, pages:**

1,2,2A,3-5 as received on 18/05/2001 with letter of 18/05/2001

**Claims, No.:**

1-5 as received on 18/05/2001 with letter of 18/05/2001

**Drawings, sheets:**

1/2,2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).  
☐ the language of publication of the international application (under Rule 48.3(b)).  
☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.  
☐ filed together with the international application in computer readable form.  
☐ furnished subsequently to this Authority in written form.  
☐ furnished subsequently to this Authority in computer readable form.  
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.  
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:  
☐ the claims, Nos.:

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International application No. PCT/NL00/00418

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

### 1. Statement

|                               |      |        |     |
|-------------------------------|------|--------|-----|
| Novelty (N)                   | Yes: | Claims | 1-5 |
|                               | No:  | Claims |     |
| Inventive step (IS)           | Yes: | Claims |     |
|                               | No:  | Claims | 1-5 |
| Industrial applicability (IA) | Yes: | Claims | 1-5 |
|                               | No:  | Claims |     |

2. Citations and explanations  
**see separate sheet**

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EXAMINATION REPORT - SEPARATE SHEET**

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International application No. PCT/NL00/00418

Each of the following documents

D2 JP-A-05 239602, English abstract and Table 1 on page 3, and

D3 JP-A-05 132743, English abstract and Table 1 on page 4,

discloses a PM made high bearing pressure part (D2) or bearing (D3) consisting of a steel alloy "A" having a composition as follows (first value D2, second value D3):

|   |               |    |               |
|---|---------------|----|---------------|
| C | 1.33 or 1.31% | Si | 0.23 or 0.24% |
|---|---------------|----|---------------|

|    |               |    |               |
|----|---------------|----|---------------|
| Mn | 0.22 or 0.23% | Cr | 4.17 or 4.19% |
|----|---------------|----|---------------|

|    |               |   |               |
|----|---------------|---|---------------|
| Mo | 5.04 or 5.03% | V | 2.78 or 2.80% |
|----|---------------|---|---------------|

|   |               |  |  |
|---|---------------|--|--|
| W | 6.24 or 6.34% |  |  |
|---|---------------|--|--|

The bearing parts known from D2 or D3 normally also comprise rollers and disks.

The composition of the roller claimed in claim 1 does not depart from that of the PM made rollers which are considered to be disclosed in D2 and D3.

Since a disk or roller "for a toroidal type IVT" is subject to high pressure and rolling wear as are the high pressure bearing rollers of D2 or D3, it is obvious to use the material of D2 or D3 for making a PM made disk or roller for a toroidal type IVT.

The subject-matter of claim 1 thus lacks an inventive step with respect to D2 or D3.

An analogous objection applies to independent claim 3 directed to an IVT and to dependent claims 2 and 4, 5 which do not add any feature which is novel with respect to D2 or D3 (the steel of claim 1 is a "M62 type steel" as mentioned in claims 2 and 5).

It is remarked that none of the claims, apart from the claimed composition, defines any features of the claimed "power roller for an IVT". Nevertheless, it is acknowledged that the claimed "power roller" departs from a roller as considered to be disclosed in D2 and D3 and that the known rollers are not suitable for being used as a "power roller" of an IVT (Examination Guidelines CIII4.8). Novelty of the subject-matter of claims 1-5 thus is acknowledged.

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The invention relates to a power roller for a toroidal type IVT.

- 5 From EP 0462637A a continuous variable transmission is shown wherein a belt extends between two pulley's of varying effective diameter. At least one contact surface of a pulley with the belt is covered with a layer realised through Powder Metallurgy. Starting from a base pulley, such layer is arranged during a later stage of manufacturing. Operational conditions of continuous variable transmission show relatively low contact
- 10 pressure between the belt and the pulley. Operation is generally dry i.e. without the presence of a lubricant.

JP 05239602 discloses the production of high bearing pressure parts starting from an alloy powder having a composition of by weight,  $\leq 2\%$  C, 2 to 5% Cr,  $\leq 2\%$  Si,  $\leq 2\%$  Mn,  $\leq 2\%$  V,  $\leq 12\%$  Mo and  $\leq 24\%$  W and satisfying  $6 \leq W_{eq} \leq 24$ .

JP 05132743 discloses a bearing remarkably improved in fatigue life and comprises by weight,  $\leq 2.0\%$  C, 2.0-5.0% Cr,  $\leq 2.0\%$  Si,  $\leq 2.0\%$  Mn,  $\leq 2.0\%$  V,  $\leq 12.0\%$  Mo,  $\leq 24.0\%$  W, and the balance Fe with inevitable impurities and where  $6 \leq W_{eq} \leq 24$  is satisfied when  $W + 2 Mo = W_{eq}$  and also  $\Delta C$  specified by  $\Delta C = C - (0.06Cr + 0.033W + 0.063Mo + 0.2V)$  satisfies  $\Delta C \leq 0$ .

- The invention relates to a power roller of an IVT component. Below an IVT has to be understood as IVT of the toroidal type and more particular the disk or rollers thereof. The contact surfaces of the disks, rollers respectively are subjected to high contact
- 15 loadings under conditions wherein a lubricant is present. With regard to roller bearings, the contact pressure is considerably higher between the circumferential surface of the powder roller and raceway of the disk. High contact fatigue strength requirements are set as well as a requirement for static load capacity, without a lubrication film being present.

- 20 It has been found that an ordinary rolling bearing steel does not meet these requirements.

The invention aims to provide a power roller which has improved properties

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making a particularly suitable for IVT, S.

According to the invention this is realised in that said power roller is integrally shaped through powder metallurgy techniques from a steel comprising

- 0.75 - 1.85 wt % C
- 5 0.10 - 0.45 wt% Si
- 0.15 - 0.50 wt% Mn
- 3.50 - 4.50 wt% Cr
- 4.00 - 11.00 wt% Mo
- 0.90 - 5.25 wt% V
- 10 0.10-13.00 wt% W
- balance Fe and impurities.

Integrally shaped is to be understood as fully comprising PM material. This in contrast to EP-0462637 wherein only a layer of PM material is provided. Only through integral manufacturing of a IVT component such as a disk and more preferably a power roller sufficient service life can be realised at the high contact fatigue loads revealing.

As indicated above the invention is used for the manufacturing of power rollers of an IVT.

According to a preferred embodiment a PM M62 type steel is used comprising:

- 1.25 - 1.35 wt % C
- 20 0.15 - 0.4 wt % Si
- 0.15 - 0.40 wt % Mn
- 3.50 - 4.25 wt % Cr
- 10.00 - 11.00 wt % Mo
- 1.80 - 2.20 wt % V
- 25 5.75 - 6.75 wt % W.

Although the costs for these kinds of steels are substantially higher than the costs for ordinary rolling bearing steel, such as ASTM A295 52100, the properties thereof make it much more suitable for the CVT/IVT disk and power roller components than ordinary rolling bearing steels. Through a suitable treatment a very high hardness of the surface of a PM M62 steel article can be realised. However, in contrast to ordinary steels produced to very high hardnesses the toughness of the core material in PM M62 does not deteriorate. This means that the toughness/hardness ratio is significantly higher than conventionally martensitic hardened ASTM A295 52100 rolling bearing steel.

2A

The invention also relates to a troïdal type IVT comprising powerrollers according to one of the preceding claims and a disk being integrally shaped through powder metallurgy techniques. Such a disk can be produced as described above for the powerroller.

5       The power metallurgy steel can be produced with any method known in the art. As example the following steps are given:

Vacuum induction melting and refining of the power metallurgy steel composition,

Nitrogen gas powder atomisation,

10       Powder grading and canning,

Hot isostatic pressing and

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Hot forging.

Other techniques for economical plastic shaping are also included.

Preferably, powder metallurgy high alloy steels are subjected to a secondary hardening treatment. Preferably, this is realised through austenising at  $1205 \pm 5^\circ\text{C}$  for 5-10 minutes followed by gas, oil or salt quenching and tempering at about  $550^\circ\text{C}$ . In the preferred embodiment given above wherein an M62 steel is used, the hardness can be as high as 67 HRC with high temperature hardness properties.

The invention will be further elucidated referring to the enclosed figures.

Fig. 1 shows an example of an IVT;

Fig. 2 shows a comparative graph for the contact stress; and

Fig. 3 shows a comparative graph for blunt notch toughness.

In fig. 1 an example of an CVT/IVT is given. In the most general embodiment the CVT/IVT comprises input disks 1 connected to the output shaft of an engine and an opposed output disk 2 connected to a drive chain or further gear box components of a vehicle or any other item which has to be driven with a variable ratio. In between are a number of power rollers 3. Power rollers 3 can be journalled on any shaft and the axis thereof is indicated by 4. This shaft can make a rotational movement in the sense of arrow 5. Through rotation of other rollers in the sense of arrow 5 the transmission ratio between the input and output disk will change. As shown in fig. 1 power roller 3 engages the input disk near its centre line whilst the output disk is engaged remote from this centre line. There is a pressure force clamping the circumferential surface of the power rollers to the raceway 8 of the input disk and the raceway 9 of the output disk respectively. This clamping force is schematically referred to by arrows 10. The CVT/IVT shown in fig. 1 is also known as 'Torotrak IVT'. Other means are also used in the art but for all embodiments it is essential that at least three power rollers are provided which make some tilting movement according to arrow 5 in order to change the ratio of transmission between an input and an output disk. It has been shown that such structure can give a 15% increased efficiency as compared to conventional automatic transmissions. In contrast to rolling bearing there is no lubrication film between the adjacent components of the structure.

The circumferential surface of each power roller as well as the raceways 8 and 9 are subjected to considerable loadings. Probably this is one of the reasons that up to now this technique was not generally accepted. For example, the maximum contact

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stress between the circumferential surface of the power rollers and the related raceway could be as high as 4 GPa. This is far higher than the contact pressure encountered in usual rolling bearings. Furthermore, the tilting movement according to arrow 5 introduces slip of the rollers relative to the disks. Such a slip is not present in rolling bearings. Fatigue cracking and fracture due to repetitive bending stresses have been reported. The area of the disk within circle 11 is particular vulnerable. This means that the combined rolling contact fatigue strength of the traction surfaces (raceways) and fatigue fracture strength should be improved. Below a very schematic overview of the loading of the several components of the CVT/IVT transmission is given.

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| IVT-Components   | ~ Characteristics  | Failure Mode   |
|--|--|--|
| Input Disk-Spine Connection  | Torsional load at spline radii                             | Structural fatigue cracking  |
| Input disk against power roller via traction fluid to stop slippage          | Up to ~3.5 GPa contact pressure                            | <ul style="list-style-type: none"> <li>•Rolling contact fatigue spalling</li> <li>•Surface distress</li> <li>•Structural load accelerated contact fatigue</li> </ul> |
| Power rollers  | Up to ~3.5 GPa contact pressure                            | <ul style="list-style-type: none"> <li>•Rolling contact fatigue spalling</li> <li>•Surface distress</li> </ul>   |
| Significant clamping forces across disk & power rollers via hydraulic piston | Bending structural stress                                  | Structural fatigue cracking  |
| Drive disk via chain sprocket  | Bending forces at output drive                             | Bending fatigue cracks   |
| Disk & power rollers   | High temperatures (up to ~ 120.°C) and structural stresses | Growth & axial clearance increase  |
| Disk & power rollers   | Vibratory loads  | Accelerated structural fatigue cracking  |

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Fig. 2 shows the rolling contact fatigue life at different contact stresses. The usual rolling bearing steel ASTM A295 52100 (dotted line) is compared with the steel according to the invention PM M62 (continuous line). The number of cycle's (L50) is in million stress cycles.

5 In fig. 3 the hardness against blunt notch toughness is shown. -.. is a 52100 steel whilst - ■ - shows PM M62. From this figure it is clear that in spite of the very high hardness of the PM M62 steel (67 HRC) , the toughness is no less than standard martensitic 52100 rolling bearing steel.

10 Through the use of a powder metallurgy steel and more particular M62 composition it is possible to decrease the size of both disks and power rollers of a CVT/IVT at the same torque output.

Although the invention has been described above referring to M62 steel as preferred embodiment, it has to be understood that other high alloy powder metallurgy steels can be used in CVT/IVT and are within the range of the invention.

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## CLAIMS

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1. Power roller for a toroidal type IVT being intergrally shaped through powder metallurgy techniques from a steel comprising
  - 5 0.75 - 1.85 wt % C
  - 0.10 - 0.45 wt% Si - - - - -
  - 0.15 - 0.50 wt% Mn
  - 3.50 - 4.50 wt% Cr - - - - -
  - 4.00 - 11.00 wt% Mo
  - 10 0.90 - 5.25 wt% V
  - 0.10-13.00 wt% W
  - balance Fe and impurities.
2. Powerroller according to claim 1, comprising a M62 type steel.
3. Toroidal type IVT comprising powerrollers according to one of the preceding  
15 claims and a disk being integrally shaped through powder metallurgy techniques.
4. Toroidal type IVT according to claim 3, wherein said disk comprises
  - 0.75 - 1.85 wt % C
  - 0.10 - 0.45 wt% Si
  - 0.15 - 0.50 wt% Mn
  - 20 3.50 - 4.50 wt% Cr
  - 4.00 - 11.00 wt% Mo
  - 0.90 - 5.25 wt% V
  - 0.10-13.00 wt% W
  - balance Fe and impurities.
- 25 5. Toroidal type IVT according to claim 3 or 4, wherein said disk comprises a M62 type steel.

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